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Original title on 712 A/B: A Technical Analysis of Speed for Expeditionary Naval Forces

Revised title:

Presented in (input and Bold one): (**WG18,** CG___, Special Session ___, Poster, Demo, or Tutorial):

This presentation is believed to be:
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Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
22 JUN 2005	**N/A**	**-**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
A Technical Analysis of Speed for Expeditionary Naval Forces	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Alidade Incorporated 31 Bridge Street Newport, RI 02840**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM201946, Military Operations Research Society Symposium (73rd) Held in West Point, NY on 21-23 June 2005 . , The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**UU**	**52**	

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A Technical Analysis of Speed for Expeditionary Naval Forces

Jeffrey R. Cares
73rd MORSS

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Speed for Expeditionary Naval Forces

Tasking

- Role of platform speed in determining requirements for Littoral Combat
  - Numbers of ships
  - Operating concepts
  - Speed advantage over CSG/ESG to provide requisite SA/BSP for AA
  - DMER5
  - Mission profile impacts

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Speed for Expeditionary Naval Forces

DMER5

- Deployment
- Management
- Exploitation
- Refueling
- Repositioning
- Recovery
- Replacement
- Redeployment

OF

Sensors

Off Board Systems

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Speed for Expeditionary Naval Forces

Platforms, Numbers, Speed

(Notional Relationships)

	Air	Surface	Submarine	Information	Space
#s	10s-100s	1s-10s	1s	1000s	1s
Speed	100s	10s	10s	100000s	1000s
Detection mode	EM/RF/EO	EM/RF/EO	Acoustic	Electronic	EM/RF/EO
Decision time	Sec	Min	Min-hours	sec-days	Hours-days

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Speed for Expeditionary Naval Forces

Analysis Parameters

- Vessel Speed:
  - 10-300 kt.
- Operating Area:
  - 160,000 nm. sq. (400 x 400 nm.); SSG/CNAN-based
  - Also have spreadsheets for other area sizes
- Sensor detection range
  - 5 nm (surface v. surface)→ Our major focus is here
  - 50 nm (air v. surface)
  - 1 nm (surf v. sub)
- Sensor endurance
  - 8hr-180days

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Analysis Bounds

- Speed
  - Deployment (ships)
  - Search
    - Ships only and Off-board Searchers
    - Perfect search and Random search
  - DMR5 (not 'E')
- Single/Multiple ship(s) and a sensor field
  - UVs and stationary sensors
  - vs. surf and sub targets

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Relationships

- Littoral Area Search Problem
  - Sensors
    - detection range and speed determines area coverage rate
    - area coverage determines number sensors emplaced
  - Sensor endurance
    - Generates revisit/replenishment rates for sensors
  - Non-random and Random
    - Best and worst cases to bound the problem (time-distance problem)
    - Probability of Detection: P_{det}=90%
  - Speed vs. searcher numbers requirement

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Speed for Expeditionary Naval Forces

Problem Timeline

- Surge from CONUS and Intra/Inter-Theater
  - Variation: Crisis response in Theater
- LCS sprint and search:
  - Lays sensor field (mobile or fixed) or conducts search
  - Issue: how much time to lay field and gain requisite Pd prior to CSG/ESG arrival?
- LCS maintains sensor field (DMR5)
  - No comments about "E"
  - Issue: Speed v. Numbers required to complete
- Objective:
  - Understand "Power Projection Lead Time" (PPLT)
  - Understand "Power Projection Lead Speed" (PPLS)

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PPLT-PPLS

- Power Projection Lead Time: The time it takes the Assured Access Force to surge ahead of the Main Body (CSG/ESG), establish a sensor field and search the AOI to a predetermined level of situational awareness*
- Power Projection Lead Speed: Speed required for the Assured Access Force to surge ahead and still have enough time to search AOI to specified level of confidence so that CSG/ESG can project power upon arrival in AOI.

*in this analysis, the proxy for 'predetermined level of situational awareness is P_{det}

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Problem

- 400 x 400 NM box
- 1 surface threat
  - The 'easiest' of a set of hard problems
  - Only one vice many things to sort through
- Assumed radar search by generic "searchers"
  - Best case search (perfect 'lawn mower' sweep)
  - Worst case search (completely random search)
- Standard for "clearance": $P_{det} = 0.9$
  - Until better quantitative measures for situational awareness are invented, P_{det} will be our proxy*

*Information Theoretic measures for 'SA' exist, little work has been done to convert theory to practical measurements and techniques that have operational meaning.

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Baseline Case w/Scenario

- Current LCS concept of operations
  - 50kt top speed
  - Single digit off board sensors
  - 2-3 LCS per CSG
- Scenario
  - CSG/ESG w/LCS squadron surges to crisis
- Question (s)
  - What is PPLT and how does it vary with speed, theater, and numbers?
  - Follow on issues/sensitivity analysis from this answer

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Specific Issues

- "Getting there" for IPB before CSG/ESG in a surge from CONUS Scenario
  - How much ahead of the battle group does LCS need to be in order to seed the sensor field for assured access
    - LCS and CSG/ESG leave at same time
    - LCS surges forward first
- How do these figures change vs. speed?
- How do these figures change vs. payload?
- How do these figures change vs. P_{det}?

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Theaters of Interest and Distances (NM)

US East Coast to Med Sea	4300
US East Coast to PG	8400
US West Coast to Korea	5300
US West Coast to PG	11000
Hawaii to Korea	3200
Hawaii to PG	8900
Intratheater-1	1000
Intratheater-2	2000

Distances are representative, not policy approved distances typically used for force structure/deployment policy calculations

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LCS Advance Arrival (Days)

	50 kt	100 kt	Time delta (50 v. 100)
US East Coast to Med Sea	5.4	7.2	1.8
US East Coast to PG	10.5	14	3.5
US West Coast to Korea	6.6	8.8	2.2
US West Coast to PG	13.8	18.3	4.5
Hawaii to Korea	4	5.3	1.3
Hawaii to PG	11.1	14.8	3.7
Intratheater-1	1.3	1.7	.4
Intratheater-2	2.5	3.3	.8

- Assumes CSG/ESG SOA of 20 kt.
- Doubling speed gains are marginal except for long transits

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LCS "Surge Ahead" Times

Deployment Distances	NM	LCS Advance Time (@ 5Okt)
US East Coast to Med	4300	5.4
US East Coast to PG	8400	10.5
US West Coast to Korea	5300	6.6
US West Coast to PG	11000	13.8
Hawaii to Korea	3200	4
Hawaii to PG	8900	11.1
Intra-Theater Crisis A	1000	1.3
Intra-Theater Crisis B	2000	2.5

- Time required for LCSs to find a single surface threat (the 'simplest' problem)
  - P_{det}=0.9
  - 50kt
  - 3 LCS
- Time of random search ('hardest')
  - 10.4 days
- Time of 'perfect' search ('easiest')
  - 4.4 days

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Analysis

- For random (hardest) search,
  - All except longest transits do not allow enough time to sweep the area.
- Implies LCS must
  - Have 'warning': surge before CSG/ESG
  - Or be forward deployed in theater of interest
- For a 'perfect' search,
  - All except the shortest transits allow enough time
  - Argues for dispersed LCS operations in theater

Strategic issue: forward deployment and stationing

Operational issue: Day-to-day operating posture with CSG/ESG

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LCS only sensitivity analysis

- 3 LCS are the only searchers
- What if required $P_{det} = 0.8$?
  - Requires 175 hr (7.3 days)
  - Save 3 days for worst case search time
  - Still requires long transits to avoid need for strategic warning or forward presence
- What if required $P_{det} = 0.95$?
  - Requires 315 hr (13 days)
  - 3 extra days required
  - Barely time for search even for longest transit distance
- Perfect search: no change in analysis
  - No uncertainty $P_{det} = 1.0$, no wasted search time.

Deployment Distances	NM	LCS Advance Time (@ 5Okt)
US East Coast to Med	4300	5.4
US East Coast to PG	8400	10.5
US West Coast to Korea	5300	6.6
US West Coast to PG	11000	13.8
Hawaii to Korea	3200	4
Hawaii to PG	8900	11.1
Intra-Theater Crisis A	1000	1.3
Intra-Theater Crisis B	2000	2.5

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LCS only sensitivity analysis

- What if LCS surged and searched at 80 kt?

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LCS-Only Sensitivity Analysis

Deployment Distances	NM	LCS Advance Time (@ 5Okt)	LCS Advance Time (@ 8Okt)
US East Coast to Med	4300	5.4	6.7
US East Coast to PG	8400	10.5	13.1
US West Coast to Korea	5300	6.6	8.3
US West Coast to PG	11000	13.8	17.2
Hawaii to Korea	3200	4	5
Hawaii to PG	8900	11.1	13.9
Intra-Theater Crisis A	1000	1.3	1.6
Intra-Theater Crisis B	2000	2.5	3.1

- LCS surge-search at 80 kt
- Time required to find a single surface threat
  - P_{det}=0.9
  - 80kt
  - 3 LCS
- Time for random search
  - 6.5 days
- Time for 'perfect' search
  - 2.8 days

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Analysis

- For random (hardest) search
  - Most deployment transits generate enough lead time to sweep the area.
- 30 kts extra speed for LCS
  - Generates shorter 'warning' requirement for surge or
  - Gives flexibility of choice in forward deployed theaters
- For a 'perfect' search,
  - All except the shortest transit allows enough time
  - Shorter 'tether' LCS operations in theater possible

Strategic issue: forward deployment and stationing

Operational issue: Day-to-day operating posture with CSG/ESG

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LCS Sensitivity Analysis

- Each LCS carries 10 off board searcher vehicles that can search at 50 kt
- Surge speed/times for LCS remain the same (50kt transit)
- LCSs deploy search vehicles upon arrival in AOI
- 30 Searchers, P_{det}=0.9, 400x400nm box:
  - Perfect search: 10.6 hr
  - Random search: 24 hr
- ***Analysis: Off board vehicles can relieve the high speed transit requirement dramatically***
  - ***Decreased search time by factor of 4-10!***
- Next issue: Maintaining this level of 'awareness'

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LCS to maintain awareness

- Search Problem:
  - 400 x 400 nm area,
  - $P_{det} = 0.9$
  - UV endurance: 24 hours
    - Remember, UVs search at max speed (50kt)
- 30 UVs in random search can achieve this requirement
- Queuing analysis determines minimum number LCS to maintain 30 vehicle search 'grid'/field/force
  - Assumes UVs uniformly distributed
  - 30 minutes to service each (arbitrary assumption)
  - LCSs go to UVs vice meet half way
- ***Result: 3 LCS sufficient to execute this task (but they operate at 50kt the whole time)***

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Maintain Awareness Sensitivity analysis

- What if UV endurance was only 12 hours?
  - 5 LCSs required
  - Halving sensor endurance ***increases*** LCS requirement by a factor of 1.7
- If UV endurance was 48 hours?
  - 1 LCS Required
  - Doubling sensor endurance ***reduces*** LCS requirement by factor of 3

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Maintain Awareness Sensitivity analysis

- What if nodes were immobile/drifting sensors and more numerous?
  - 80 nodes,
  - 24 hour endurance,
  - 50kt LCS
- 5 LCS required
  - Double endurance, drop to 3 LCS
  - Double nodes, increase to 8 LCS

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Complex Systems Research

Process Innovation & Analysis

Strategic Investment Advice

Future Concept Generation

Corporate/Government War Games & Events

QUESTIONS?

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Speed for Expeditionary Naval Forces

Chart Appendix

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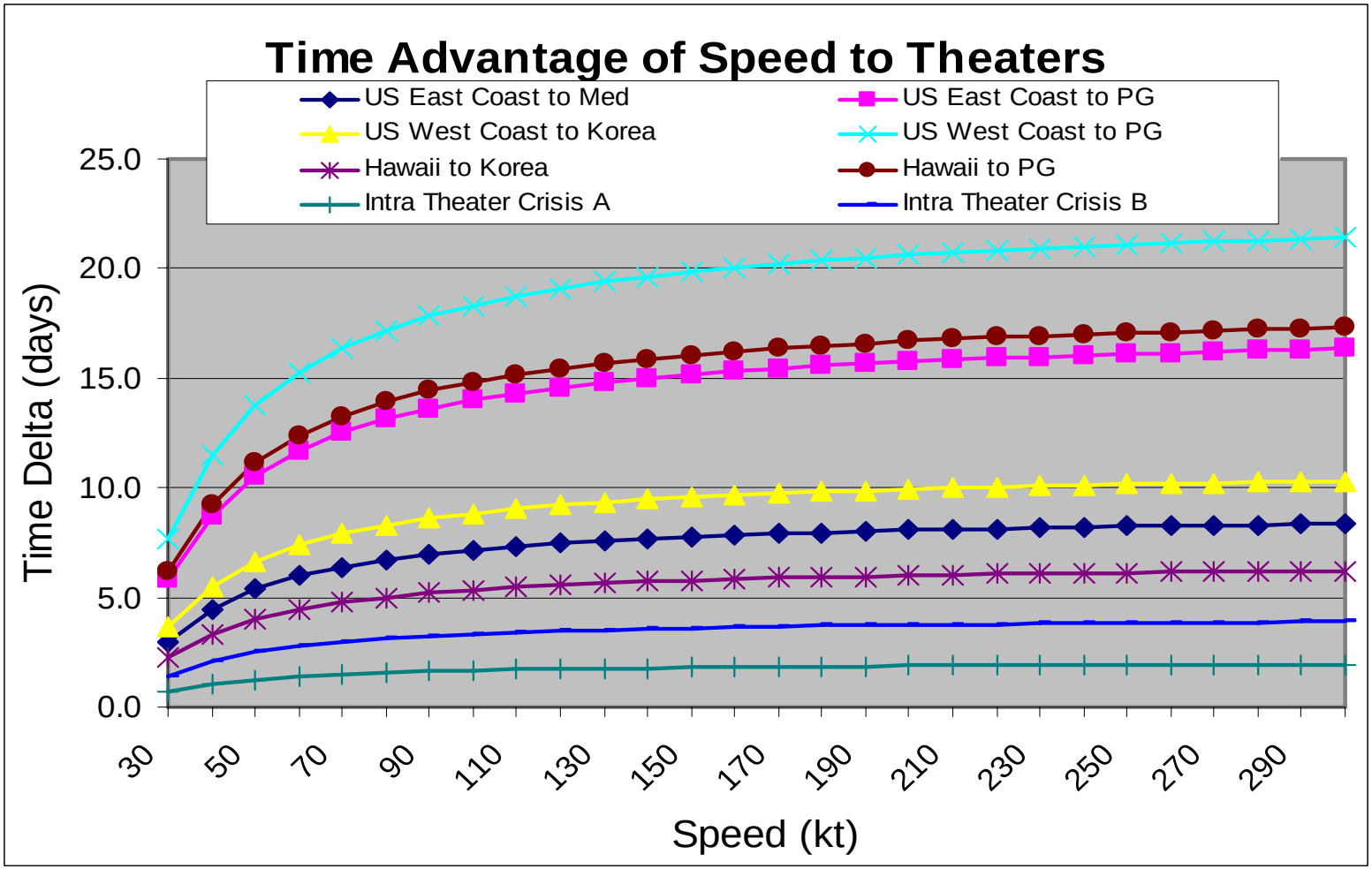
LCS vs. CSG/ESG



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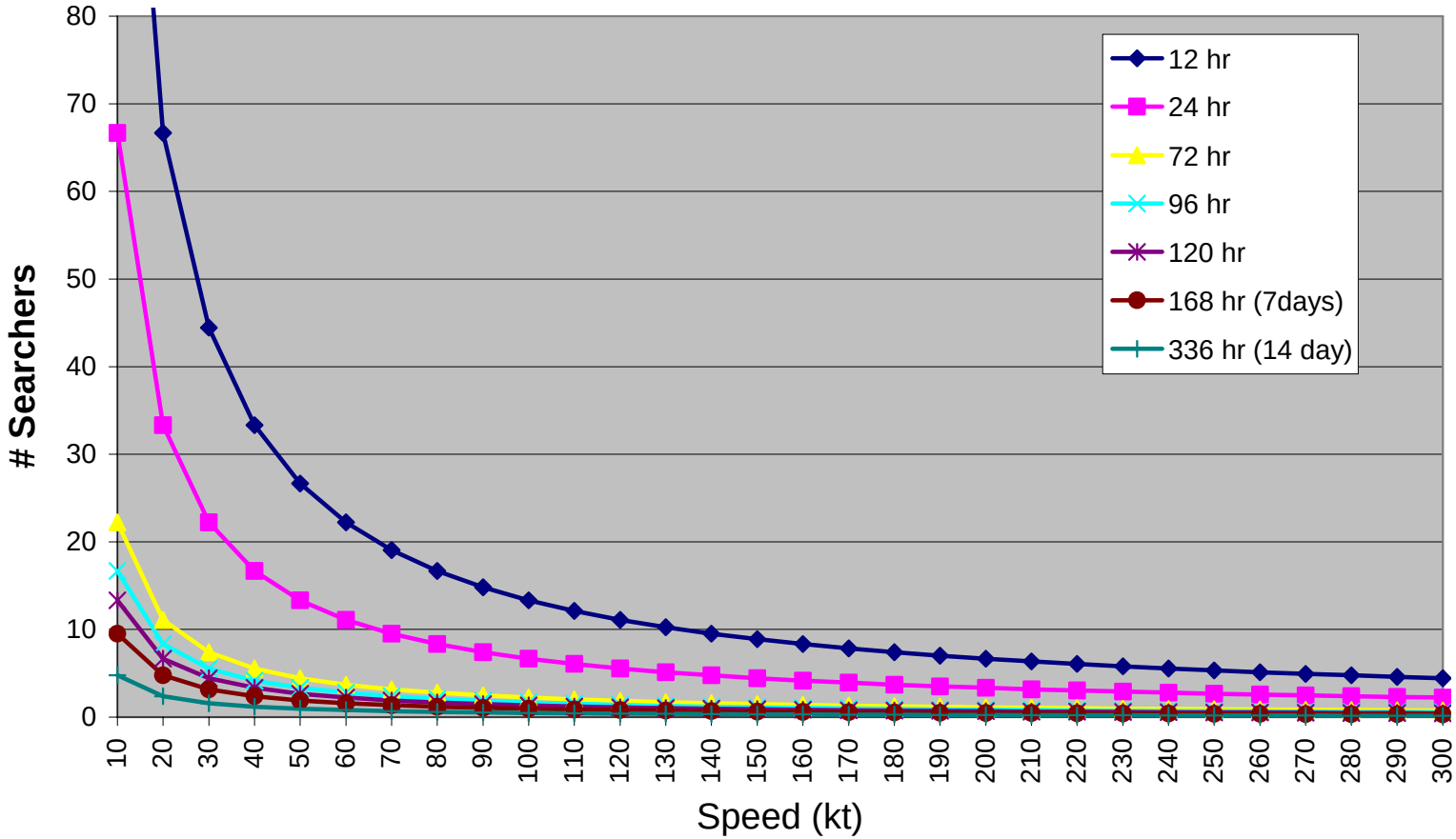
LCS Required for Perfect Search 400x400 nm box



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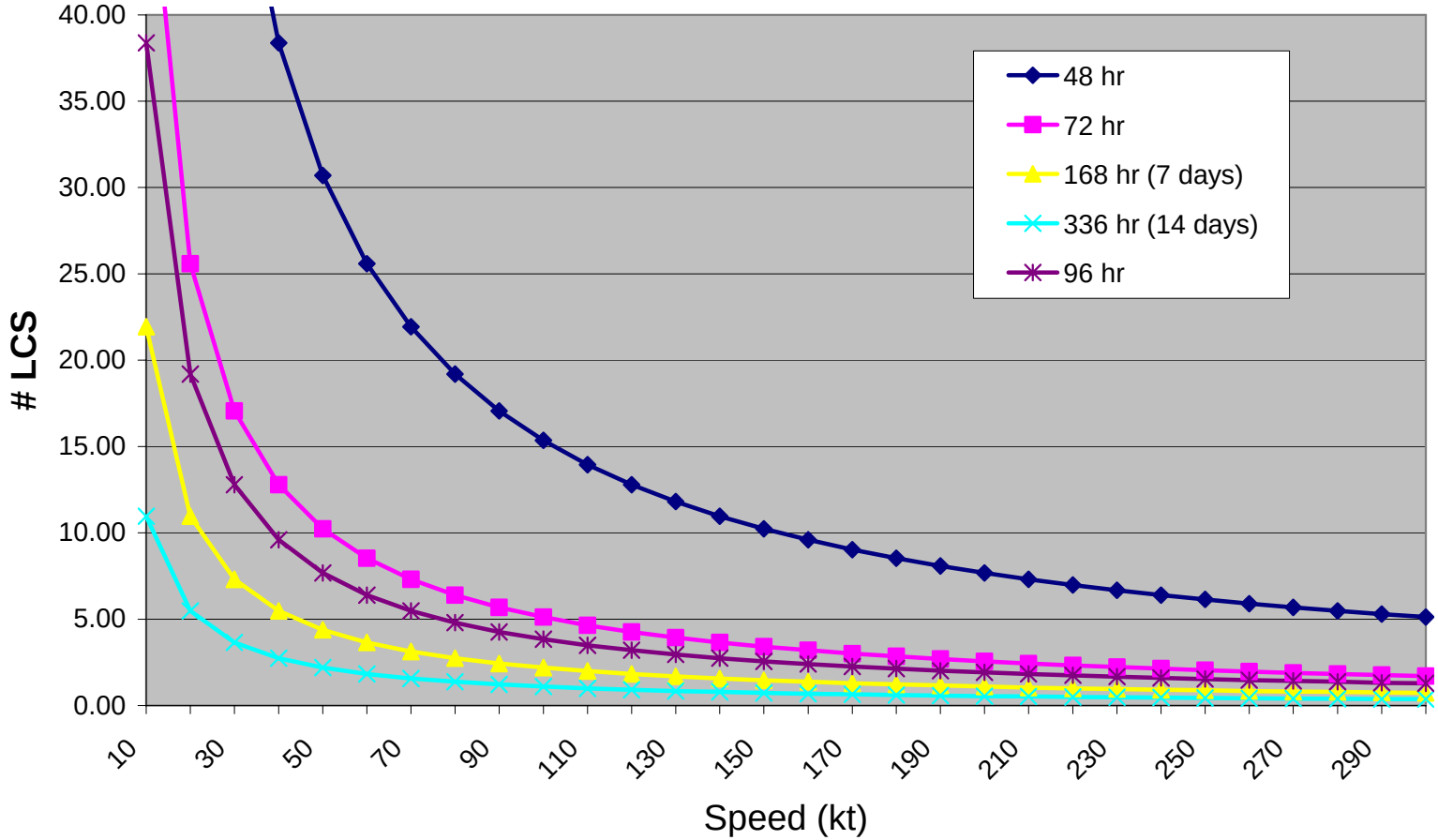
LCS Required for Pd=0.9 vs. Surface Ship(s)



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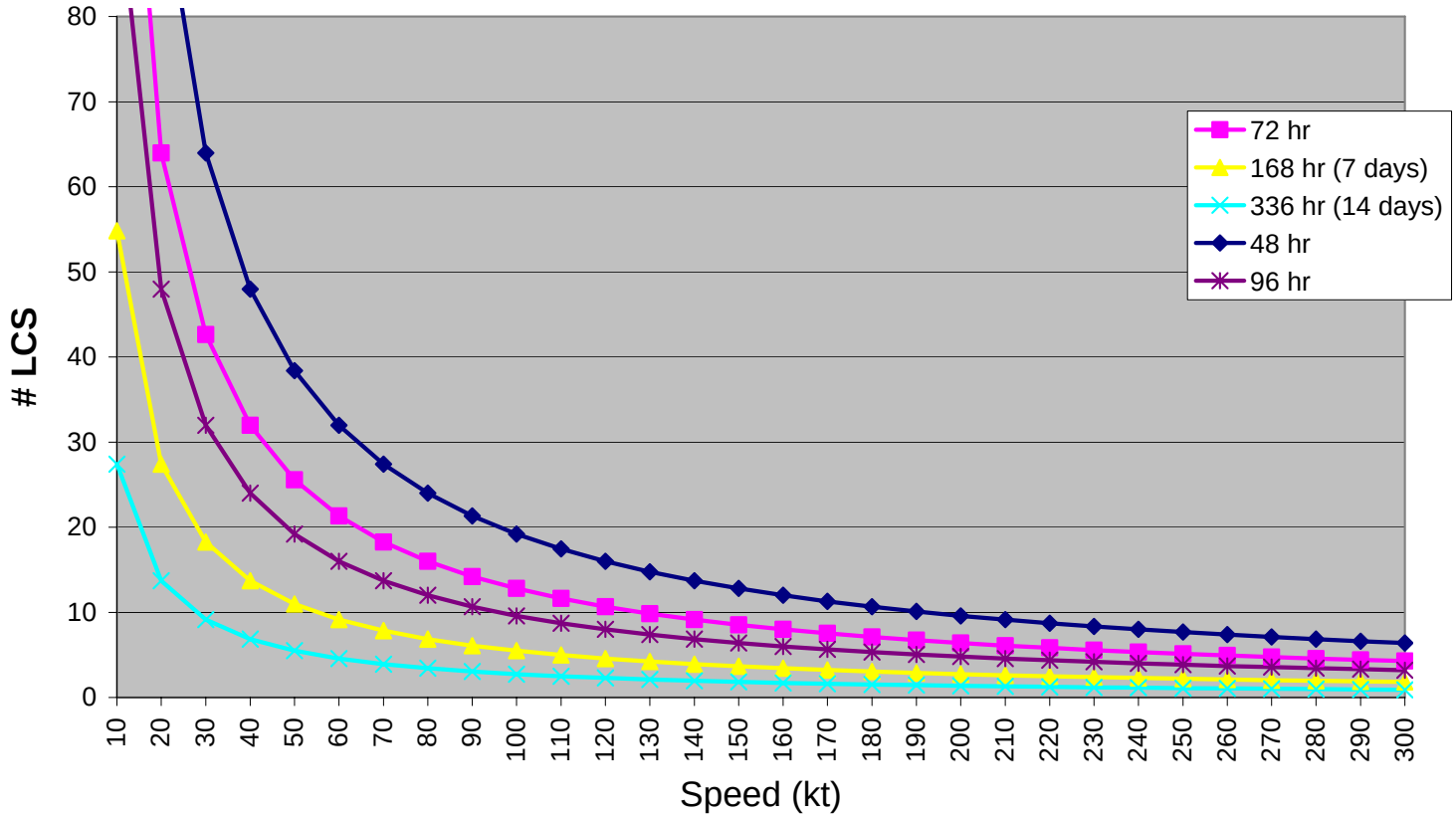
LCS Required for Pd=0.9 vs. subsurface target



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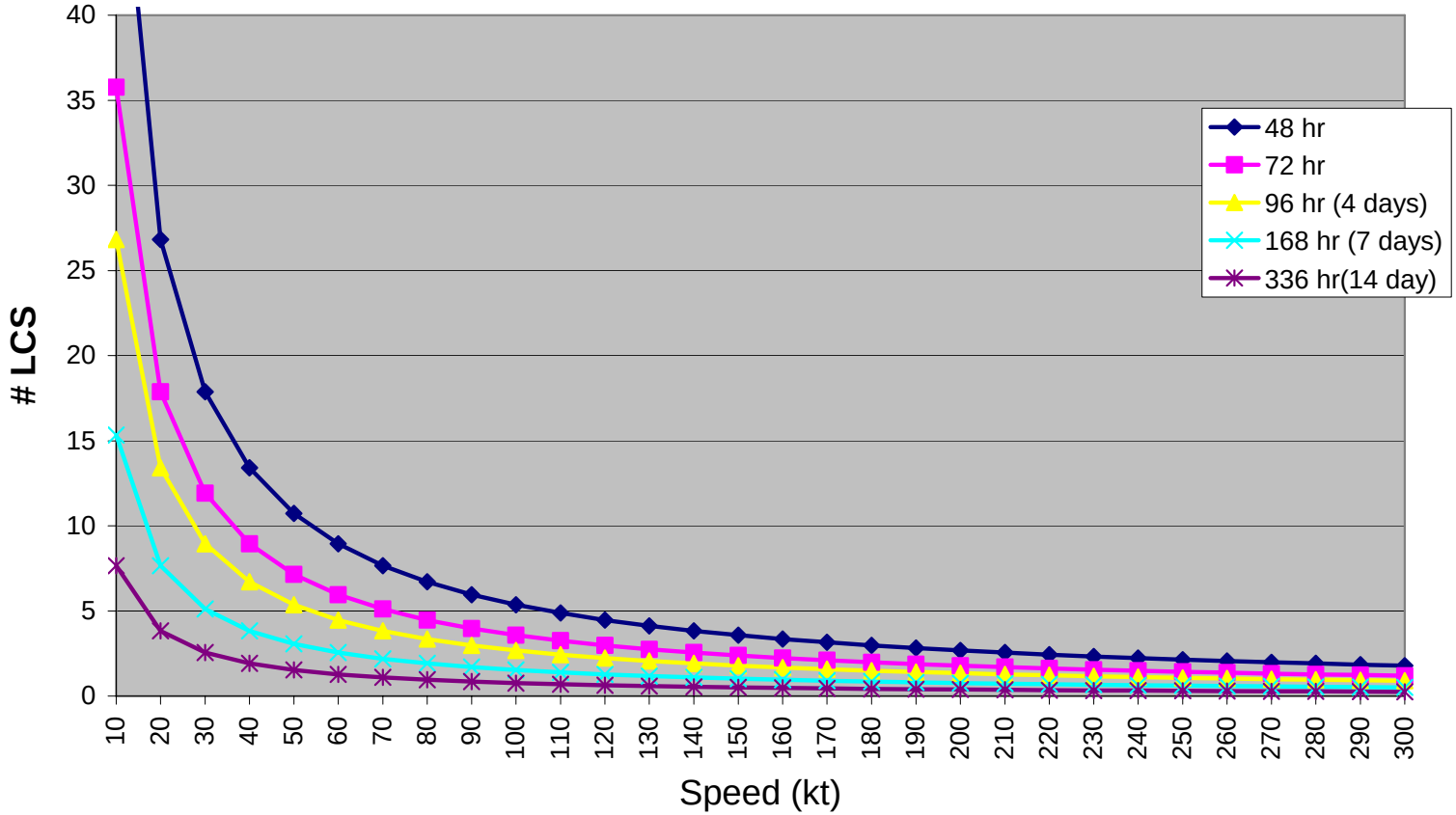
LCS Required for Pd=0.8



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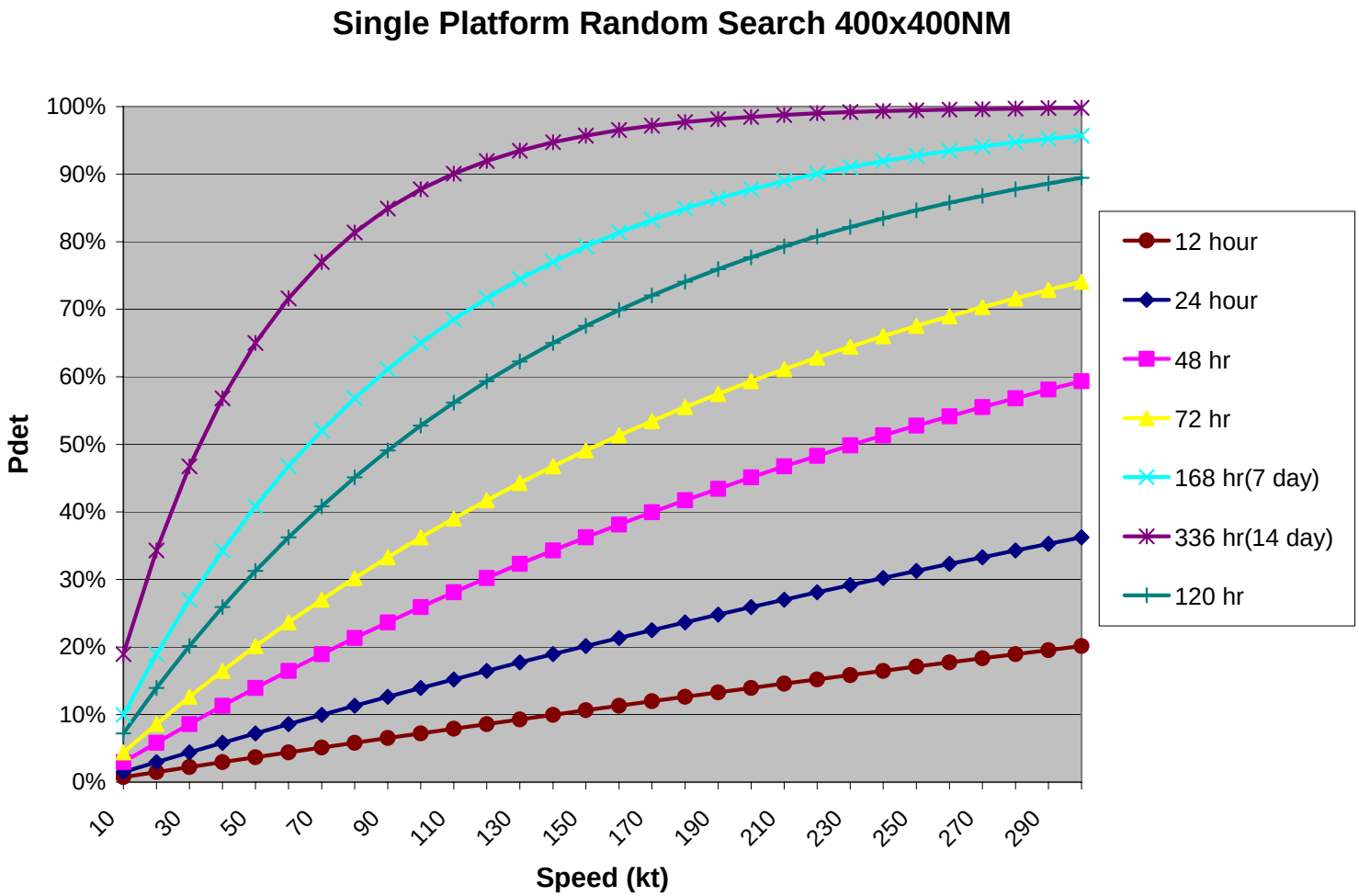

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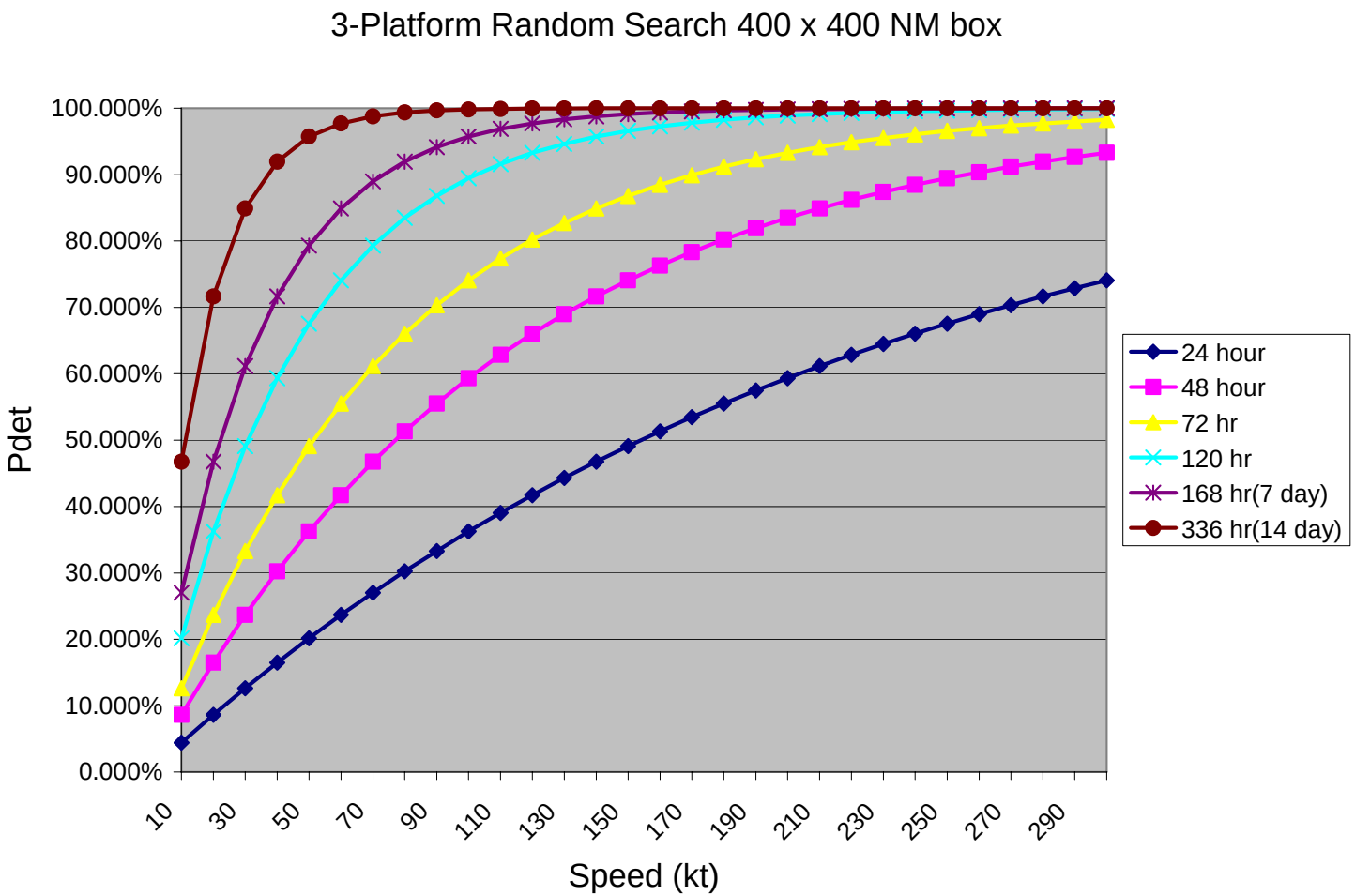

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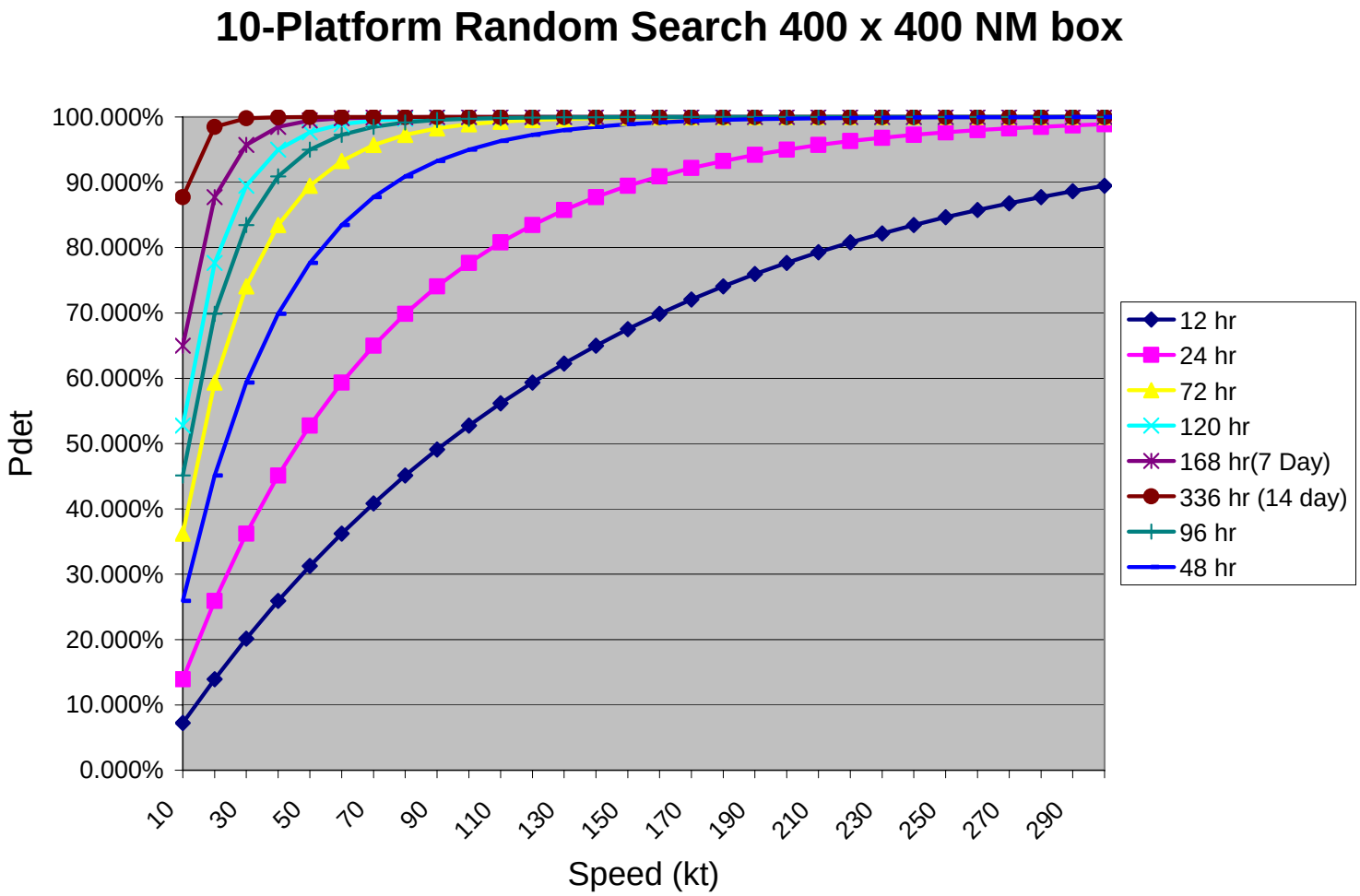

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30 platform random search

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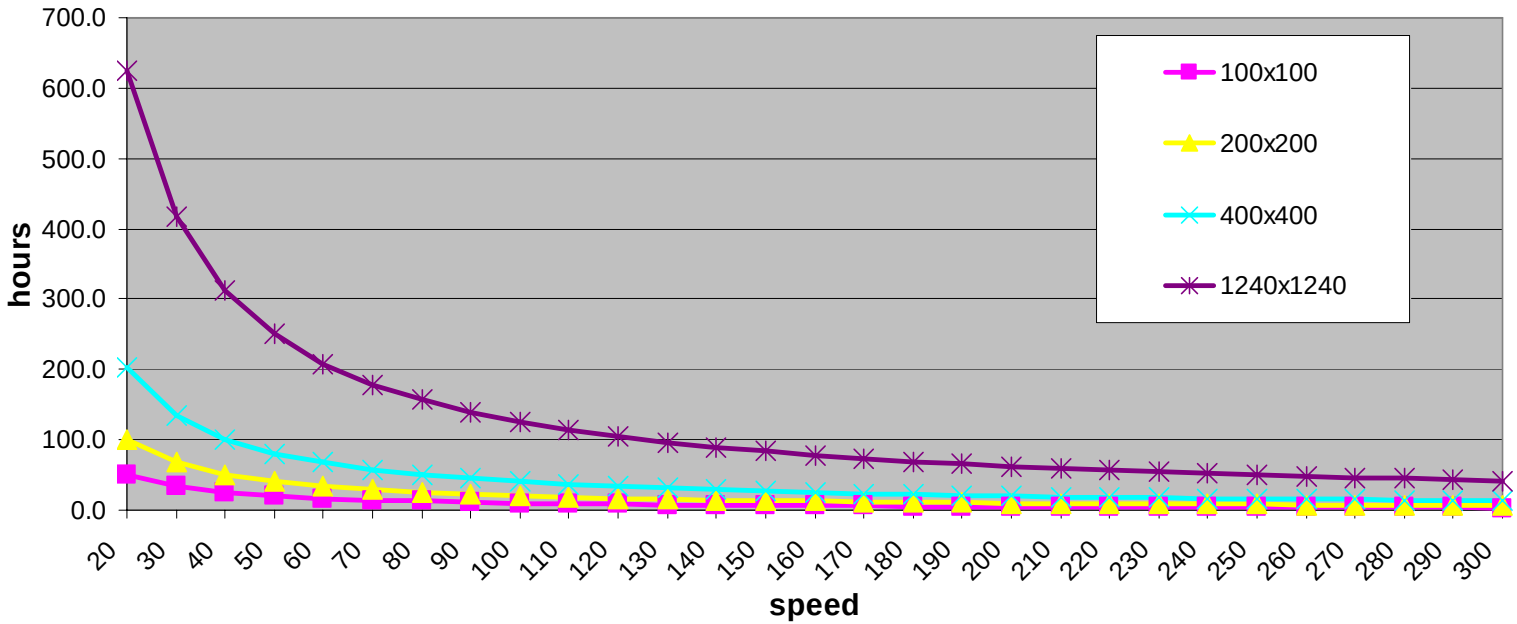
Time to Seed a Fixed Size Sensor Field

Speed for Expeditionary Naval Forces



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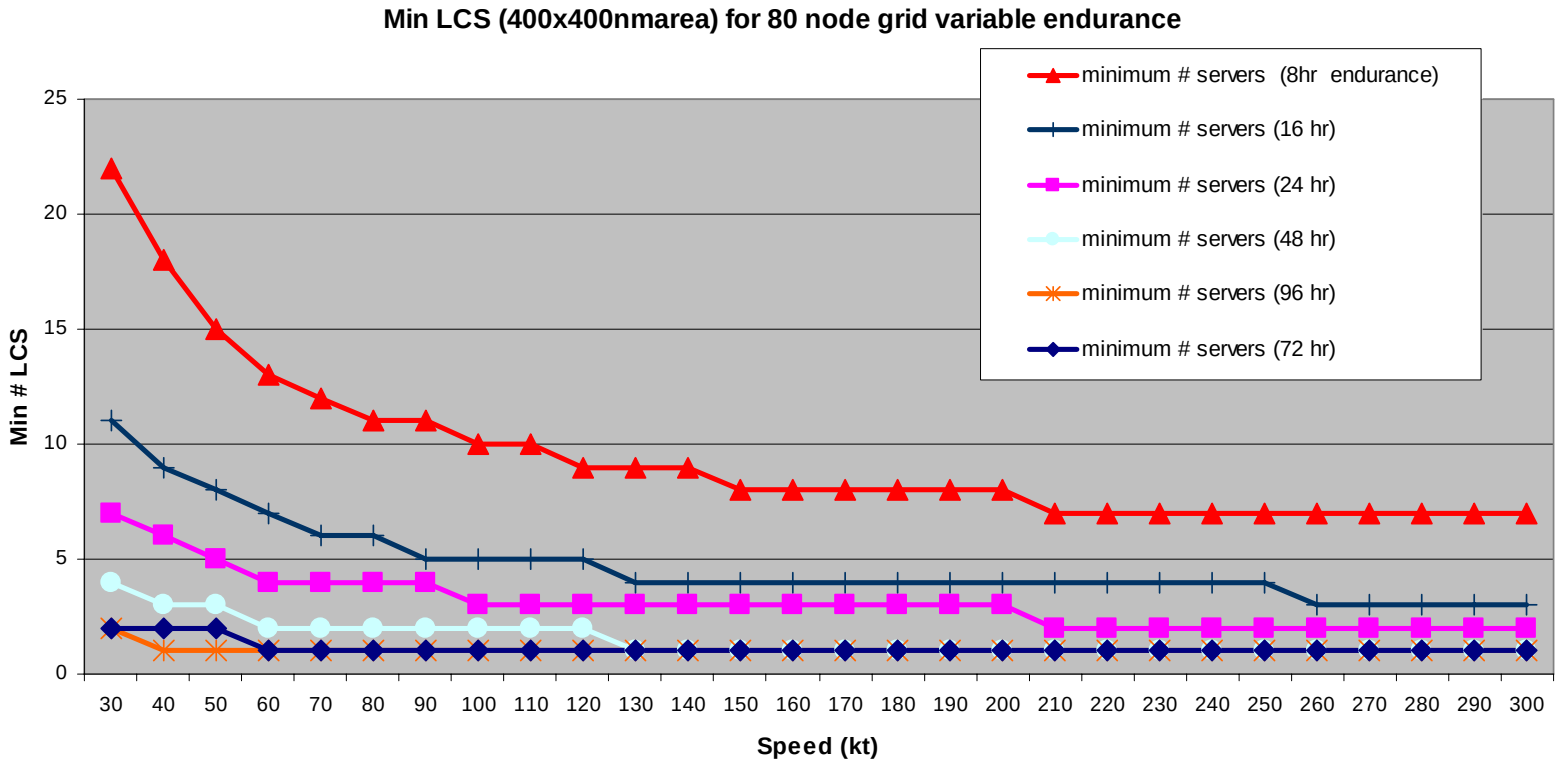
Minimum # LCS to maintain an 80 Node grid



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BACK UPS

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LCSs to service UV/Sensor Fields

- 3 LCS: 50 and 225 node fields, 24 hr endurance, 400 x 400 nm box
  - 60 kt. (50)
  - Cannot accomplish for 225 nodes unless endurance increases:
    - 48 hr: 130kt.
    - 72 hr: 50 kt.
- 50kt LCS:
  - 4 LCS (50)
  - 10 LCS (225)
- 80kt LCS:
  - 3 LCS (50)
  - 8 LCS (225)

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Architecting a Problem

- Littoral Search Area Problem
- Area:
  - 1240NM (2000KM) x 1240NM (2000)KM (~1.5M nm. sq.)
    - NWDC AA briefing
    - 1.5M nm. sq. generates ridiculous numbers
  - More useful areas for analysis:
    - 100NM x 100NM (10,000 nm. sq.)
    - 200NM x 200NM (40,000 nm. sq.)
    - 400NM x 400NM (160,000 nm. sq.)
- Missions/tasks: DMR5 a sensor or unmanned vehicle field
  - Sensor area coverage and detection range drives number of sensors emplaced
  - Sensor endurance and failure rate determine R5 (service) demand
- Highlighted issues:
  - Revisit/replenishment rates for sensors: # LCS to maintain field
  - Single ship speed requirement
  - Speed vs. ship numbers requirement
- Tradespace information:
  - Speed, numbers, geography

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Time to Seed a Fixed Size Sensor Field

	Speed	20	30	40	50	60	70	80	90	100
Field Size	Distance									
100x100	1009.3	2.1	1.4	1.1	0.8	0.7	0.6	***0.5***	0.5	***0.4***
200x200	2018.5	4.2	2.8	2.1	1.7	1.4	1.2	1.1	0.9	***0.8***
400x400	4037.0	8.4	5.6	4.2	3.4	2.8	2.4	2.1	1.9	1.7
1240x1240	12514.7	26.1	17.4	13.0	10.4	8.7	7.4	6.5	5.8	5.2

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area L	800	800
area W	100	100
nmsq	80000	80000
grid spacing	20	20
nodes (#)	240	240
total track to lay grid	4030	4030
deploy speed	10	20
deploy time-hr	403	201.5
deploy time-days	16.8	8.4
speed delta		10
time delta-hr		-201.5
percent time delta		50%

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LCS to Service Sensor/UV Fields

- Geographic area (A)
  - 100x100NM
  - 200x200NM
  - 1240x1240NM (PESG OV-1=2000x2000KM)
- Number of Nodes (N)
  - 80 nodes (variable density)
  - Constant density (based on 80 nodes in 200x200NM area)
- LCS speed (s)
  - 30-300kt
  - Covers a 3x-10x increase in speed capability
- Node endurance (e)
  - 8, 16, 24, 48, 72 hours
  - Determines the 'demand for service signal'

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Analysis

- The fundamental comparison here is to find the time that an LCS or squadron of LCS can arrive in theater before the CSG/ESG so that the field can be placed and 'situational awareness' established for follow-on forces.
  - Note: the time that it takes to build an adequate 'picture' of the battle space is beyond the scope of this project as it requires a separate information theoretic analysis.
- For a 100x100 nm field of 80 sensors
  - 2 days at 20 kt, decreasing linearly in direct proportion to speed
  - A 5 kt speed advantage gets the LCS in theater in greater that 2 days in all cases.
- 200X200:
  - 4 days, same
- 400X400
  - 8 days, same
- 1024x1024
  - 26 days

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Operational Level Example

- Speed at the Operational Level of War:
- Repositioning of forces for:
  - TBMD—Operational utility of TBM umbrellas
  - Forcible Entry—Operational utility of 'feints'
  - Blockade of Port—Operational Utility of limited cognitive span/information capability

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Thoughts on Analysis problem

- Numbers of off board vehicles vs. speed
- 100nm coastline
  - Missile tubes engagement envelope vs. speed tending requirements, etc.
- Oblique questions
  - Why do I need a 30 kt mmcruiser to protect the DAL?
  - Need a 2 kt arsenal boat protected by 60kt lcs using MUSICAL
- Operational applications
  - DMER5 across peace, combat, transit/logistics/sustainment
- Looking for a reference document and more studies

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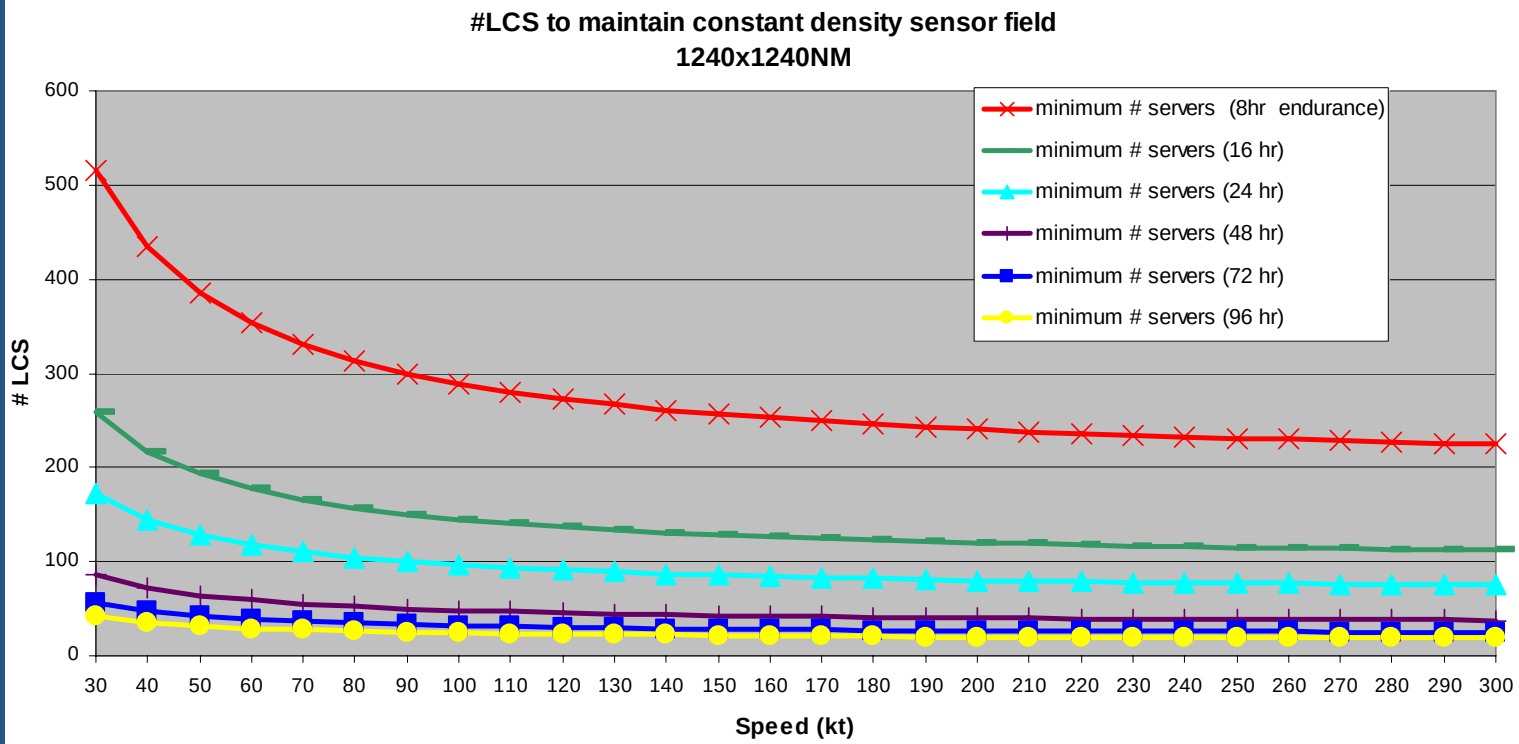
Results-Constant Node Density



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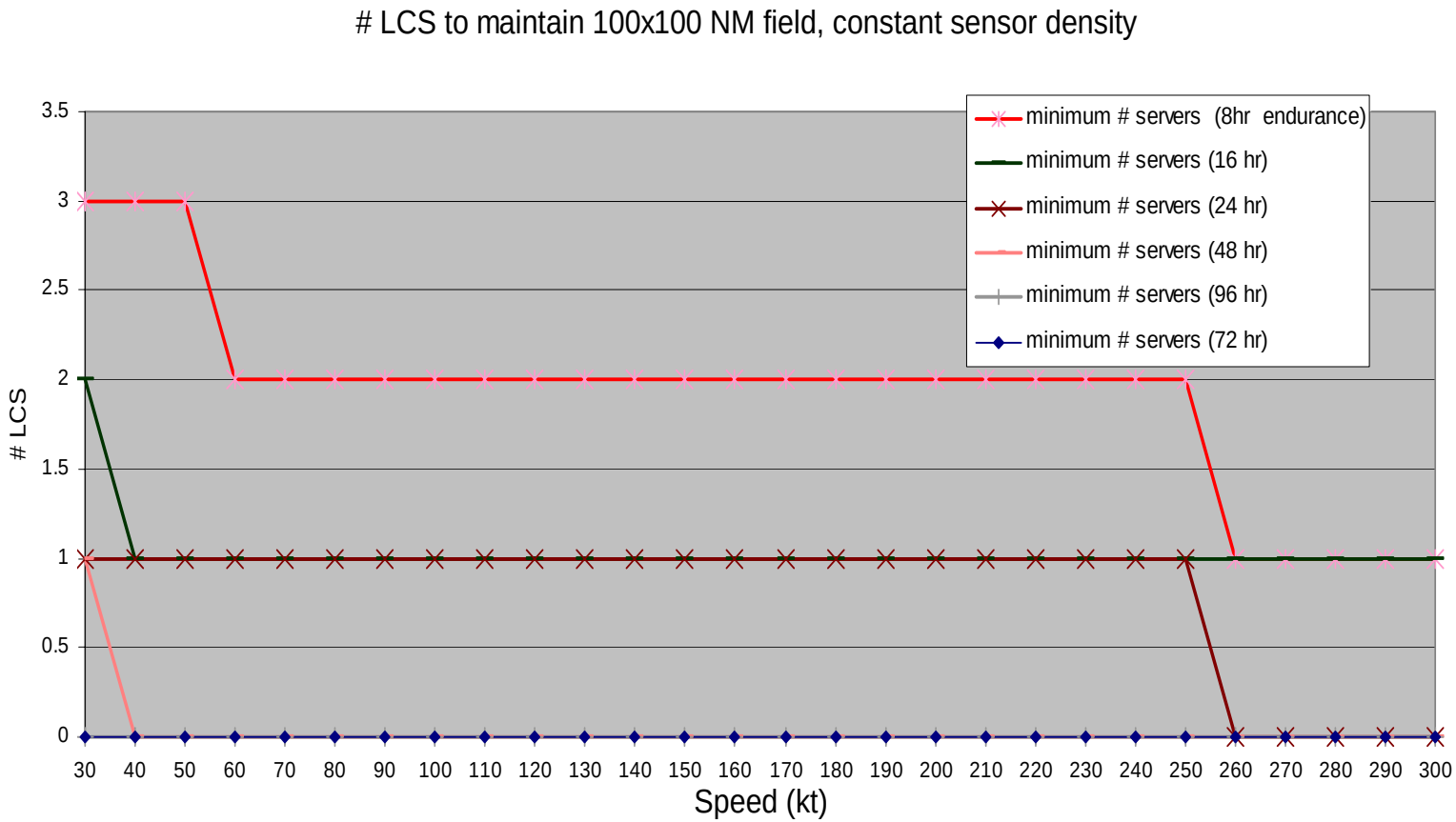

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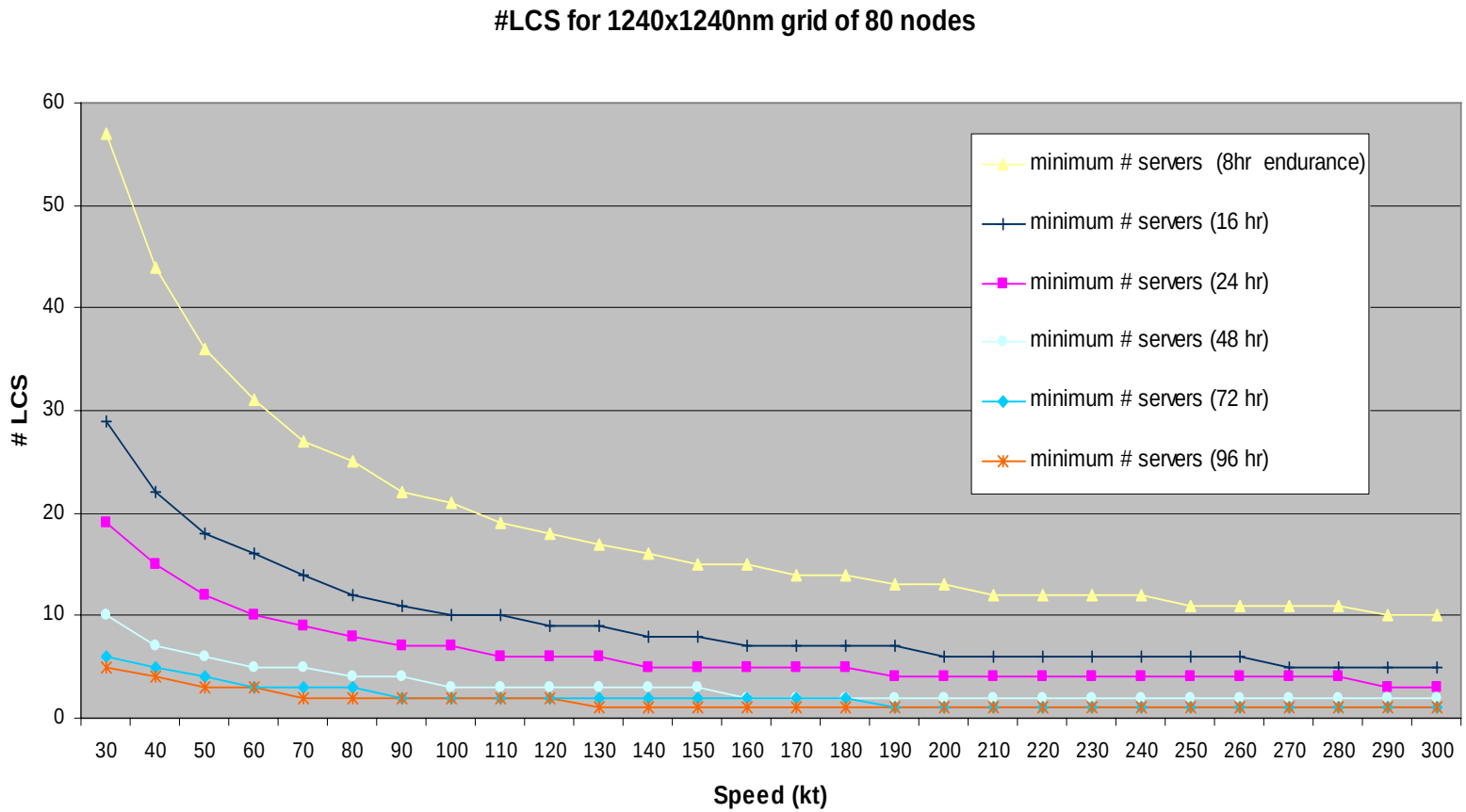

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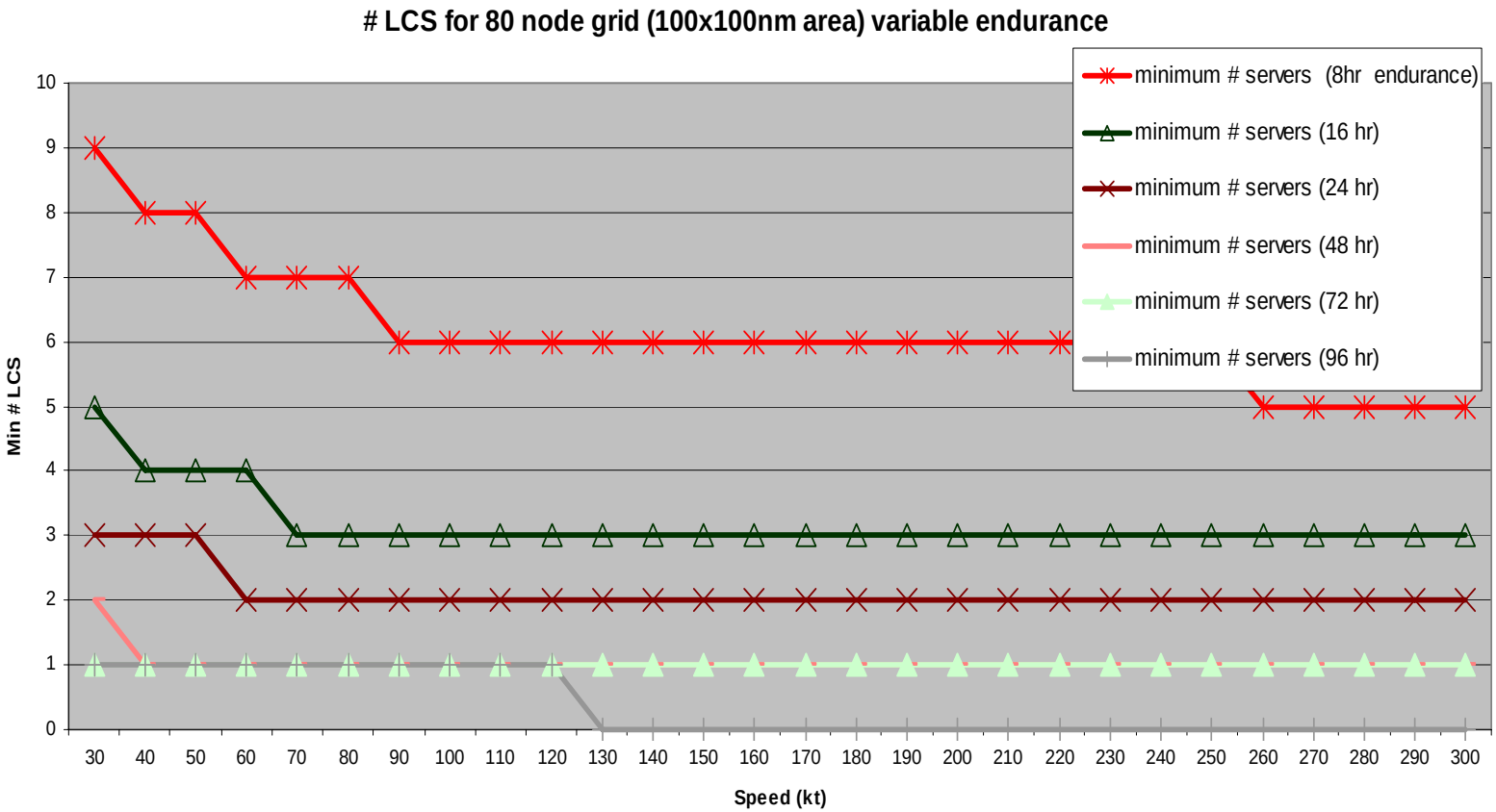

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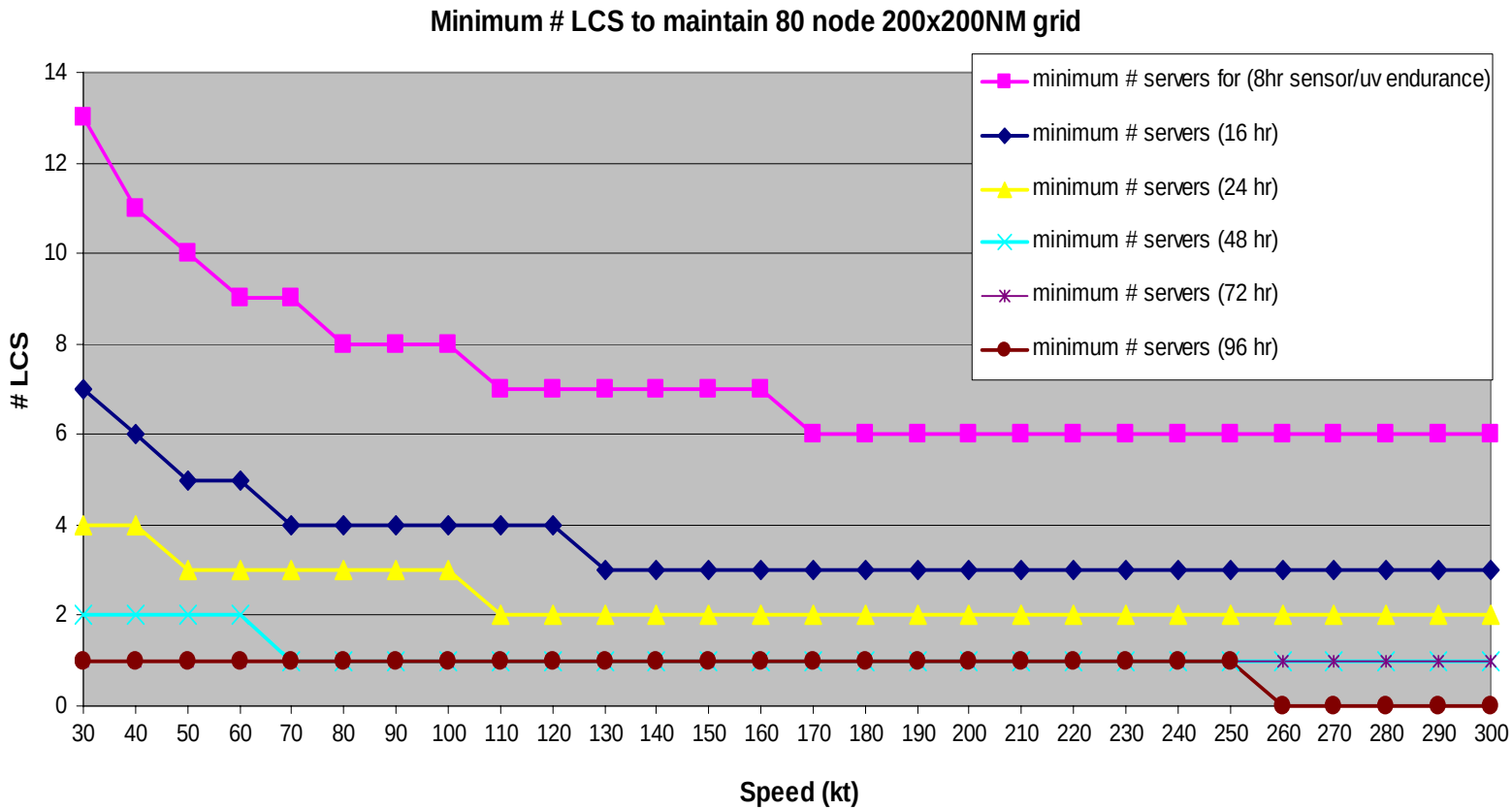

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